CANADA

DEPARTMENT OF MINES

AND

TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

WATER SUPPLY PAPER No. 261

GROUND-WATER RESOURCES OF THE RURAL MUNICIPALITY OF NORTH STAR NO. 531 SASKATCHEWAN

Records Collected by C. O. Hage

Compilation by G. S. Hume and C. O. Hage

OTTAWA

1947

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MINES AND GEOLOGY BRANCH
BUREAU OF GEOLOGY AND TOPOGRAPHY

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INTRODUCTION

Information on the ground-water resources of east-central Alberta and western Saskatchewan was collected, mostly in 1935, during the progress of geological investigations for oil and gas. The region studied extends from Edmonton in the west to Battleford in the east, and from township 32 on the south to township 59 in western Alberta, township 63 in eastern Alberta, and in part as far north as township 56 in western Saskatchewan.

This region is crossed by North Saskatchewan and Battle Rivers, and includes other more or less permanent streams. Most of the lakes within the area, however, are alkaline, and water is obtained in wells from two sources, namely, from water-bearing sands in surface or glacial deposits, and from sands in the underlying bedrock.

A division has been made in the well records, in so far as possible, between glacial and bedrock water-bearing sands. In investigations for oil and gas, however, the bedrock wells were used to trace the lateral extent of geological formations, with the result that the records deal more particularly with this type of well. No detailed studies were made of the glacial materials in relation to the water-supply, nor were the glacial deposits mapped adequately for this purpose. In almost all of the region investigated in Alberta, and in all but the northeast part of the region studied in Saskatchewan, water can be obtained from bedrock. In a few places, however, the water from the shallower bedrock sands is unsatisfactory, and deeper drilling may be necessary.

The water records were obtained mostly from the well owners, some of whom had acquired the land after the water supply had been found, and hence had no personal knowledge of the water-bearing beds that had been encountered in their wells. Also the elevations of the wells were taken by aneroid barometer and are, consequently, only approximate. In spite of these defects, however, it is hoped that the publication of these water records may prove of value to farmers, town authorities, and drillers in their efforts to obtain water supplies adequate for their needs.

In collecting this information several field parties were employed. These were under the direction of Professors R. L. Rutherford and P. S. Warren of the University of Alberta, C. H. Crickmay of Vancouver, and C. O. Hage, until recently a member of the Geological Survey. The oil and gas investigations of which these water records are a part were undertaken under the general supervision of G. S. Hume.

Publication of Results

The essential information pertaining to ground-water conditions is being issued in reports that in Saskatchewan cover each municipality, and in Alberta cover each square block of sixteen townships beginning at the 4th meridian and lying between the correction lines. The secretary treasurer of each municipality in Saskatchewan and Alberta will be supplied with the information covering that municipality. Copies of the reports will also be available for study at offices of the Provincial and Federal Government Departments. Further assistance in the interpretation of the reports may be obtained by applying to the Chief Geologist, Geological Survey, Ottawa. Technical terms used in the reports are defined in the glossary.

How to Use the Report

Anyone desiring information concering ground water in any particular locality will find the available data listed in the well records. These should be consulted to see if a supply of water is likely to be found in shallow wells sunk in the glacial drift, or whether a better supply may be obtained at greater depth in the underlying bedrock formations. The wells in glacial drift commonly show no regional level, as the sands or gravels in which the water occurs are irregularly distributed and of limited extent. As the surface of the ground is uneven, the best means of comparing water wells is by the elevations of their water-bearing beds. For any particular well this elevation is obtained by subtracting the figure for the depth of the well to the water-bearing bed from that for the surface elevation at the well. For convenience both the elevation of the wells and the elevation of the water-bearing bed or beds in each well are given in the well record tables. Where water is obtained from bedrock, the name of the formation in which the water-bearing sand occurs is also listed in these tables, and this information should be used in conjunction with that provided on bedrock formations, pages 4 to 8, which describes these formations and gives their thickness and sequence. Where the level of the water-bearing sand is known, its depth at any point can easily be calculated by substracting its elevation, as given in the well record tables, from the elevation of the surface at that point.

With each report is a map consisting of two figures. Figure 1 shows the bedrock formations that will be encountered beneath the unconsolidated surface deposits. Figure 2 shows the position of all wells for which records are available, the class of well at each location, and the contour line or lines of equal surface elevation. The elevation at any location can thus be roughly judged from the nearest contour line, and the records of the wells show at what levels water is likely to be encountered. The depth of the well can then be calculated, and some information on the character and quantity of water can be obtained from a study of the records of surrounding wells.

GLOSSARY OF TERMS USED

Alkaline. The term "alkaline" has been applied rather loosely to some ground waters that have a peculiar and disagreeable taste. In the Prairie Provinces, water that is commonly described as alkaline usually contains a large amount of sodium sulphate and magnesium sulphate, the principal constituents of Glauber's salt and Epsom salts respectively. Most of the so called alkaline waters are more correctly termed sulphate waters, many of which may be used for stock without ill effect. Water that tastes strongly of common salt is described as salty.

Alluvium. Deposits of earth, clay, silt, sand, gravel, and other material on the flood plains of modern streams and in lake beds.

Aquifer or Water-bearing Horizon. A porous bed, lens, or pocket in unconsolidated deposits or in bedrock that carries water.

Buried pre-Glacial Stream Channels. A channel carved into bedrock by a stream before the advance of the continental ice-sheet, and subsequently either partly or wholly filled in by sands, gravels, and boulder clay deposited by the ice-sheet or later agencies.

Bedrock. Bedrock, as here used, refers to partly or wholly consolidated deposits of gravel, sand, silt, clay, and marl that are older than the glacial drift.

Coal Seam. The same as a coal bed. A deposit of carbonaceous material formed from the remains of plants by partial decomposition and burial.

Contour. A line on a map joining points that have the same elevation above sea-level.

Continental Ice-Sheet. The great ice-sheet that covered most of the surface of Canada many thousands of years ago.

Escarpment. A cliff or a relatively steep slope separating level or gently sloping areas.

Flood Plain. A flat part in a river valley ordinarily above water but covered by water when the river is in flood.

Glacial Drift. The loose, unconsolidated surface deposits of sand, gravel, and clay, or a mixture of these, that were deposited by the continental ice-sheet. Clay containing boulders forms part of the drift and is referred to as glacial till or boulder clay. The glacial drift occurs in several forms:

(1) Ground Moraine. A boulder clay or till plain (includes areas where the glacial drift is very thin and the surface uneven).

(2) Terminal Moraine or Moraine. A hilly tract of country formed by glacial drift that was laid down at the margin of the continental ice-sheet during its retreat. The surface is characterized by irregular hills and undrained basins.

(3) Glacial Outwash. Sand and gravel plains or deltas formed by streams that issued from the continental ice-sheet.

(4) Glacial Lake Deposits. Sand and clay plains formed in glacial lakes during the retreat of the ice-sheet.

Ground Water. Sub-surface water, or water that occurs below the surface of the land.

Hydrostatic Pressure. The pressure that causes water in a well to rise above the point at which it is first encountered.

Impervious or Impermeable. Beds, such as fine clays or shale, are considered to be impervious or impermeable when they do not permit of the perceptible passage or movement of ground water.

Pervious or Permeable. Beds are pervious when they permit of the perceptible passage or movement of ground water, as for example porous sands, gravel, and sandstone.

Pre-Glacial Land Surface. The surface of the land before it was covered by the continental ice-sheet.

Recent Deposits. Deposits that have been laid down by the agencies of water and wind since the disappearance of the continental ice-sheet.

Unconsolidated Deposits. The mantle or covering of alluvium and glacial drift consisting of loose sand, gravel, clay, and boulders that overlie the bedrock.

Water-table. The upper limit of the part of the ground wholly saturated with water. This may be very near the surface or many feet below it.

Wells. Holes sunk into the earth so as to reach a supply of water. When no water is obtained they are referred to as dry holes. Wells in which water is encountered are of three classes.

(1) Wells in which the water is under sufficient pressure to flow above the surface of the ground.

(2) Wells in which the water is under pressure but does not rise to the surface.

(3) Wells in which the water does not rise above the water table.

BEDROCK FORMATIONS OF WEST-CENTRAL SASKATCHEWAN AND EAST-CENTRAL ALBERTA

The formations that outcrop in west-central Saskatchewan are an extension of similar formations that occur in east-central Alberta. They are of Upper Cretaceious age, and consist entirely of relatively soft shales and sands, with some bands of hard sandstone and layers of ironstone nodules. The succession, character, and estimated thickness of the formations are shown in the following table:

Formation	Character	Thickness Feet
Edmonton	Grey to white, bentonitic sands and sandstones with grey and greenish shales; coal seams prominent in some areas, as at Castor, Alberta.	1,000 to 1,150
Bearpaw	Dark shales, green sands with smooth black chert pebbles; partly non-marine, with white bentonitic sands, carbonaceous shales or thin coal seams similar to those in Pale Beds; shales at certain horizons contain lobster claw nodules and marine fossils; at other horizons are abundant selenite crystals.	300 to 600 thins rapidly to the north-west
Pale and Variegated Beds	Light grey sands with bentonite; soft, dark grey and light grey shales with selenite and ironstone; carbonaceous shales and coal seams; abundant selenite crystals in certain layers.	950 to 1,200 in Czar-Tit Hills area; may be thinner elsewhere
Birch Lake	Grey sand and sandstone in upper part; middle part of shales and sandy shales, thinly laminated; lower part with grey and yellow weathering sands; oyster bed commonly at base.	100 in west, but less to east and south
Grizzly Bear	Mostly dark grey shale of marine origin, with a few minor sand horizons; selenite crystals and nodules up to 6 or 8 inches in diameter	Maximum, 100
Ribstone Creek	Grey sands and sandstones at the top and bottom, with intermediate sands and shales; thin coal seam in the vicinity of Wainwright; mostly non-marine, but middle shale in some areas is marine.	Maximum, 325 at Viking; thins eastward
Lea Park	Dark grey shales and sandy shales with nodules of ironstone; a sand 70 feet thick 110 feet below the top of the formation in the Ribstone area, Alberta.	950 to 1,100

Edmonton Formation

The name Edmonton formation was first applied to the beds containing coal in the Edmonton area, and later to the same beds in adjoining areas. The formation has a total thickness of 1,000 to 1,150 feet, but is bevelled off eastward and the east edge of the formation follows a northwest line from Coronation through Tofield to a point on North Saskatchewan River about midway between Edmonton and Fort Saskatchewan. No Edmonton beds occur northeast of this line, but the formation becomes progressively thicker to the southwest due to the fact that the beds incline in that direction and the surface bevels across them.

The Edmonton formation consists of poorly bedded grey and greenish clay shales, coal seams, and sands and sandstones that contain clay and a white material known as bentonite. This material when wet is very sticky and swells greatly in volume, and when dry tends to give a white appearance to the beds containing it. Such beds are relatively impervious to water, and at the surface produce the "burns" of barren ground where vegetation is scanty or absent.

Water is relatively abundant in the Edmonton formation, which contains much sand, commonly in the form of isolated lenses distributed irregularly through the formation. Consequently, there is little uniformity in the depth of wells even within a small area. Water also occurs commonly with coal seams and, unlike the sand lenses, these beds are much more regular and persistent. In contrast with the water from the bentonitic sands, which is generally "soft", water from the coal seams, as the water from the shallow surface deposits, may be "hard". The basal beds of the Edmonton formation usually contain fresh water, but this may become brackish locally where the underlying Bearpaw beds contain highly alkaline or salty water.

Bearpaw Formation

In southern Alberta, where the Bearpaw formation is thickest, the beds composing it are mainly shales that have been deposited in sea water. In the area north of township 32 the formation thins to the northwest and becomes a shoreline deposit composed of shales containing bentonite, impure sands, and thin coal seams. In some areas, as at Ryley and near Monitor, and in the Neutral Hills, the Bearpaw contains pebble beds. At Ryley these are consolidated into a conglomerate, but mostly the pebbles are loosely distributed in shale or sandy beds.

In the area immediately north of township 32 the Bearpaw occupies a widespread belt beneath the glacial drift, but farther northwest the belt narrows, and at Ryley and northwestward it is only a few miles wide. This belt crosses North Saskatchewan River about midway between Edmonton and Fort Saskatchewan. Bearpaw beds form the main bedrock deposits of the Neutral Hills. Farther south, where they have an exposed thickness of at least 400 feet, they contain green sands, and beds of marine shale interfinger with the bentonitic shales and sands of the underlying formation. To the north, on the banks of North Saskatchewan River, the division between the Bearpaw and the overlying and underlying formations is indefinite, and the thickness of beds of Bearpaw age is relatively small.

The water in the Ryley area is from the Bearpaw formation, and is salty. In other areas to the south the marine Bearpaw formation carries green sand beds that yield fresh water, but commonly a much better supply is found by drilling through the Bearpaw into the underlying Pale Beds.

In Saskatchewan, Bearpaw beds occur southeast of Maclin and south of Luseland and Kerrobert. Only the basal beds are present, and these contain green sands that are commonly water-bearing.

Pale and Variegated Beds

Underlying the Bearpaw formation is a succession of bentonitic sands, shales, and sandy shales containing a few coal seams. The upper part of this succession, due to the bentonitic content, is commonly light coloured and has been described as the Pale Beds, whereas the lower part is darker, and is known as Variegated Beds. In part, dark shales are present in both Pale and Variegated Beds; others are greenish, grey, brown, and dark chocolate, carbonaceous types. The sands may also be yellow, but where bentonite is present it imparts a light colour to the beds. Both Pale and Variegated Beds are characterized by the presence of thin seams of ironstone, commonly dark reddish, but in part purplish, Selenite (gypsum) crystals are, in places, abundant in the shales.

The best sections of Pale Beds exposed in the region are in the Tit Hills, southwest of Czar. These hills carry a thin capping of Bearpaw shales, beneath which, and around Bruce Lake, more than 200 feet of Pale Beds are exposed. The total thickness of Pale and Variegated Beds in the Tit Hills area is about 970 feet. Variegated Beds outcrop near Hawkins on the Canadian National Railway west of Wainwright, but no area exposes the complete succession, which is considered to comprise about 200 feet of beds.

Records of wells drilled into the Pale and Variegated Beds do not, in general, indicate lateral persistence of sands for long distances, nor any uniform average depth to water-bearing sands in a local area. This points to the conclusion that the sands are mainly local lenses, but as such lenses are numerous, few wells fail to obtain water. In the Cadogan area many flowing wells have been obtained from sands about midway in the succession. In western Saskatchewan Paleland Variegated Beds occur over a wide area from Maclin and Kerrobert northeast through Wilkie to the Eagle Hills, south of Battleford. Numerous outcrops occur in the area south of Unity at Muddy Lake, but south and east around Biggar these beds are almost wholly concealed by glacial drift.

The water from the sands of the Pale and Variegated Beds is generally soft. The supply, apparently, is dependent in part on the size of the sand body that contains the water and in part on the ease with which water may be replenished in the sand. Small sand lenses surrounded by shales may be filled with water that has infiltrated into them, but when tapped by a well the supply may be very slowly replenished. In many instances such wells yield only a small supply, although this is commonly persistent and regular.

Birch Lake Formation

The Birch Lake formation underlies the Variegated Beds, but in many areas the division is not sharp. The type area of the formation is along the north shore of Birch Lake south of Innisfree, where a section 65 feet thick, composed mostly of sand, is exposed. The total thickness of the formation in this area is about 100 feet, and although this is dominantly sand a central part is composed of alternating thin sand and shale beds. At the base of the formation, in a number of places, is an oyster bed, and this is exposed in a road cut in a section 73 feet thick on the east side of Buffalo Coulée in sec. 3, tp. 47, rge. 7, W. 4th mer. In both upper and lower parts of the formation the sand is commonly massive and outcrops tend to consolidate into hard, nodular masses from a foot to a few feet in diameter. Apparently these are formed through the deposition of salts from the water that finds an outlet at the outcrops. In fact, in some areas the sand may be traced along the side of a hill by the presence of small springs or nodular masses of sandstone.

The Birch Lake formation occurs under the drift and in outcrops in a large area south of North Saskatchewan River and northeast of a line from Willingdon to Innisfree and Minburn. East of this area the southwest boundary is more irregular, but outcrops are persistent on the banks of Battle River from a few miles north of Hardisty to and beyond the mouth of Grizzly Bear Coulée in tp. 47, rge. 5. It is believed, too, that a large area near Edgerton and Chauvin is underlain by the Birch Lake formation and that it extends southeastward into Saskatchewan around Manitou Lake and southeast to Vera.

It is thought that the Birch Lake formation thins eastward from its type section at Birch Lake, and that it loses its identity in western Saskatchewan. Deep wells drilled at Czar, Castor, and elsewhere no longer show the Birch Lake as a clearly recognizable sand formation, so that its southern limit beneath younger formations is unknown. Wherever it occurs as a sand, however, it is water-bearing, although in some areas the sand is apparently too fine to yield any considerable volume of water. In other areas, however, it persistently yields good wells. There is no apparent uniformity in the character of the water, which is either hard or soft in different wells in the same general area. Direct contact with surface waters that contain calcium sulphates may in time change a "soft" water well to a "hard" water well, and many wells are not sufficiently cased to prevent the percolation of water from surface sands into the well, and hence into the deeper, soft water producing sands. In part this accounts for the change in character of the water in a well, a feature that has been noticed by many well owners.

Grizzly Bear Formation

The type locality for the Grizzly Bear formation, which underlies the Birch Lake beds, is near the mouth of Grizzly Bear Coulée, a tributary of Battle River with outlet in tp. 47, rge. 5. The formation is mainly composed of dark shales that were deposited in sea water. At the mouth of Grizzly Bear Coulée two shale sections, each about 100 feet thick, are separated by a zone of thin sand beds. It is now recognized that the upper section is the Grizzly Bear shale, and that the lower one, very similar in character and also deposited in sea water, occurs in the next lower formation, the Ribstone Creek. The Grizzly Bear shale contains a thin nodular zone about 50 feet above the base, that is, at about the centre of the formation. This zone is sandy, and is believed to yield water in various wells. Other thin sands, in places water-bearing, are also present. The impervious nature of the Grizzly Bear shales makes the overlying Birch Lake sand a strong acquifer, as water collects in the sand above the shale. The contact of the Birch Lake and Grizzly Bear formations can be traced in some places by the occurrence of springs issuing from the base of the Birch Lake sand even where this is not exposed.

Grizzly Bear shales occur in a road cut on the south side of Battle River near the highway bridge at Fabyan. The shales in this area are about 100 feet thick. It is thought they extend as far west as the Viking gas field, where they have been recognized in samples from deep wells. It is probable, however, that the shales thin westward and thicken eastward so that their general form is a wedge between both higher and lower sand beds. The position of the thin edge of the wedge to the west is unknown, but evidently the Grizzly Bear marine shale underlies a large area in east-central Alberta extending into Saskatchewan mainly in the area south of Battle River.

Ribstone Creek Formation

The type area of the Ribstone Creek formation is on Ribstone Creek near its junction with Battle River in tp. 45, rge. 1, W. 4th mer. At this place the lower sand beds of the formation are well exposed. The upper part of the lower sand member of this formation outcrops on the north side of Battle River, in the northeast part of sec. 26, tp. 47, rge. 5, near the mouth of Grizzly Bear Coulée. Above it, higher on the bank and at a short distance from the river, there is a 12 foot zone of carbonaceous and coaly beds in two layers, each about 2 feet thick, separated by 8 feet of shale. Above this are 90 feet of dark shales that are thought to have been deposited in sea water, that is, they are marine shales. These marine shales in turn are overlain by a sandy zone about 20 feet thick containing oysters in the basal part. This sandy zone is the upper sand member of the Ribstone Creek formation.

It thickens to the east and west from the Grizzly Bear area but is probably at no place much more than 50 feet thick.

The lower sand member of the Ribstone Creek formation also varies in thickness from a minimum of about 25 feet. On the banks of Vermilion Creek, north of Mannville, the basal sand is at least 60, and may be 75, feet thick. It is overlain by shaly sand and sandy shale beds, which replace the shale beds in the central part of the formation as exposed at the mouth of Grizzly Bear Coulée. In the Wainwright area, where the formation has been drilled in deep wells, the basal sand is 60 feet thick, with the central part composed of shale containing sand streaks. The upper sand member is about 20 feet thick in this area. The total thickness of the formation in the Wainwright area is 180 to 200 feet, but this increases to the west and in the Viking area exceeds 300 feet.

The Ribstone Creek formation is widely exposed in a northwest-trending belt in east-central Alberta. The southwest boundary of this northwest-trending belt passes through the mouth of Grizzly Bear Coulée in tp. 47, rge. 5, and beyond to the Two Hills area in tp. 54, rge. 12, whereas the northeast boundary crosses North Saskatchewan River southwest of Elk Point and extends northwest to include an area slightly north of St. Paul des Metis and Vilna to tp. 60, rge. 14. Within this belt water wells are common in the Ribstone Creek sands, which are almost without exception water-bearing in some part of the formation. The limits of the belt to the northeast determine the limits of water from this source, but to the southwest of the belt, as here outlined, water may be obtained in this formation by drilling through the younger beds that overlie it. The Ribstone Creek sands are a prolific source of water in many places and hence the distribution of this formation is of considerable economic importance. Where the formation consists of upper and lower sands with a central shale zone only the sands are water-bearing, although thin sand members may occur in the shale. Where the formation is largely sand the distribution of water may be in any part of the formation, although the upper and lower sands are perhaps the better aquifers. To the east of Alberta, along Battle River and Big Coulée in Saskatchewan, the Ribstone Creek sands are marine. Marine conditions apparently become more prevalent to the southeast and it is believed that in this direction the sands are gradually replaced by marine shales. Thus at some distance southeast of Battleford the Ribstone Creek formation loses its identity and its equivalents are shales in a marine succession.

Lea Park Formation

The Lea Park formation is largely a marine shale, and only in the upper 180 feet is there any water. In the Dina area south of Lloydminster the upper beds of the Lea Park consist of silty shales about 110 feet thick underlain by silty sands 70 feet thick. Below these sands are marine shales only, and these yield no fresh water either in east-central Alberta or west-central Saskatchewan. The sand in the upper Lea Park formation is thus the lowest freshwater aquifer within a very large area. The extent of this sand in the Lea Park, particularly to the northeast, is not known, but as the strata in east-central Alberta have a southwest inclination, progressively lower beds occur at the surface to the northeast. Thus at a short distance beyond the northeast boundary of the Ribstone Creek formation, as previously outlined, the sand in the upper Lea Park reaches the surface, and represents the last bedrock aquifer in that direction. Farther northeast water must be obtained from glacial or surface deposits only. In Alberta this area without fresh water in the bedrock includes the country north of North Saskatchewan River in the vicinity of Frog Lake and a large area extending to and beyond Beaver River. In this area, however, more fresh water streams are present than farther south, and bush lands help to retain the surface waters. The area northeast of North Saskatchewan River in Saskatchewan is almost wholly within the Lea Park formation, where water can be found only in surface deposits.

WATER ANALYSES

Introduction

Analyses were made of water samples collected from a large number of wells in west-central Saskatchewan. Their purpose was to determine the chemical characteristics of the waters from different geological horizons, and thereby assist in making correlations of the strata in which the waters occur. Although this was the main objective of the analyses, it was also realized that a knowledge of the mineral content of the water is of interest and value to the consumer. The analyses were all made in the laboratory of the Water Supply and Borings Section of the Geological Survey, Ottawa.

Discussion of Chemical Determinations

The dissolved mineral constituents vary with the material encountered by the water in its migration to the reservoir bed. The mineral salts present are referred to as the total dissolved solids, and they represent the residue when the water is completely evaporated. This is expressed quantitatively as "parts per million", which refers to the proportion by weight in 1,000,000 parts of water. A salt when dissolved in water separates into two chemical units called "radicals", and these are expressed as such in the chemical analyses. In the one group is included the metallic elements of calcium (Ca), magnesium (Mg), and sodium (Na), and in the other group are the sulphate (SO4), chloride (Cl), and carbonate (CO_3) radicals.

The analyses indicate only the amounts of the previously mentioned radicals, thus neglecting any silica, alumina, potash, or iron that may be present. It will be noticed that in most instances the total solids are accounted for by the sum total of the radicals as shown by the analyses. Actually, the residue when the water is completely evaporated still retains some combined water of crystallization, so that the figures for the "total solids" are higher than the sum total of the radicals as determined. These radicals are also "calculated in assumed combinations" to indicate the theoretical amounts of different salts present in the water. The same method was followed in each analysis, so that the table presents a consistent record of the different compounds present.

Mineral Constituents Present

Calcium. Calcium (Ca) in the water comes from mineral particles present in the surface deposits, the chief source being limestone, gypsum, and dolomite. Fossil shells provide a source of calcium, as does also the decomposition of igneous rocks. The common compounds of calcium are calcium carbonate ($CaCO_3$) and calcium sulphate ($CaSO_4$).

Magnesium. Magnesium (Mg) is a common constituent of many igneous rocks and, therefore, very prevalent in ground water. Dolomite, a carbonate of calcium and magnesium, is also a source of the mineral. The sulphate of magnesia ($MgSO_4$) combines with water to form "Epsom salts" and renders the water unwholesome if present in large amounts.

Sodium. Sodium (Na) is derived from a number of the important rock-forming minerals, so that sodium sulphate and carbonate are very common in ground waters. Sodium sulphate (Na_2SO_4) combines with water to form "Glauber's salt" and excessive amounts make the water unsuitable for drinking purposes. Sodium carbonate (Na_2CO_3) or "black alkali" waters are mostly soft, the degree of softness depending upon the ratio of sodium carbonate to the calcium and magnesium salts. Waters containing sodium carbonate in excess of 200 parts per million are unsuitable for irrigation purposes[1]. Sodium sulphate is less

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1 "The extreme limit of salts for irrigation is taken to be 70 parts per 100,000, but plants will not tolerate more than 10 to 20 parts per 100,000 of black alkali (alkaline carbonates and bicarbonates)" Frank Dixey in "A Practical Handbook of Water Supply", Thos. Murby & Co., 1931, p. 254.

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harmful.

Sulphates. The sulphate (SO_4) salts referred to in these analyses are calcium sulphate ($CaSO_4$), magnesium sulphate ($MgSO_4$), and sodium sulphate (Na_2SO_4).

Chloride. Chlorine (Cl) is with a few exceptions, expressed as sodium chloride (NaCl), that is, common table salt. It is found in all of the analyses, most of the waters containing less than 200 parts per million, but some as much as 2,000 or 3,000 parts. These waters have a brackish taste.

Alkalinity. The alkalinity determined in these water analyses is based on the assumption that the only salts present in the samples that will neutralize acids are carbonates, and that, consequently, the degree of alkalinity is proportional to the amount of the carbonate radical (CO_3) present.

Hardness. The hardness of water is the total hardness, and has been determined by the amount of a standard soap solution required to form a lather that will stand up (persist) for 2 minutes. Hardness is of two kinds, temporary and permanent. Temporary hardness is caused by calcium and magnesium bicarbonates, which are soluble in water but are precipitated as insoluble normal carbonates by boiling, as shown by the scale that forms in teakettles. Permanent hardness is caused by the presence of calcium and magnesium sulphates, and is not removed by boiling. The two forms of hardness are not distinguished in the water analyses. Waters grade from very soft to very hard, and can be classified according to the following system[2]:

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2 The "Examination of Waters and Water Supplies", Thresh & Beale, page 21, Fourth Ed. 1933.

A water under 50 degrees (that is, parts per million) of hardness may be said to be very soft.
A water with 50 to 100 degrees of hardness may be said to be moderately soft.
A water with 100 to 150 degrees of hardness may be said to be moderately hard.
A water with more than 200 and less than 300 degress of hardness may be said to be hard.
A water with more than 300 degrees of hardness may be said to be very hard.

Hard waters are usually high in calcium carbonate. Almost all of the waters from the glacial drift are of this type, especially those associated with sand and gravel deposits that come close to the surface.

In soft water the calcium carbonate has been replaced by sodium carbonate, due to natural reagents present in the sand and clays. Bentonite and glauconite are two such reagents known to be present. Montmorillinite, one of the clay-forming minerals, has the same property of softening water, owing to the absorbed sodium that is available for chemical reaction[1].

1

Piper, A. M. "Ground Water in Southwestern Pennsylvania", Penn. Geol. Surv., 4th series.

If surface water reaches the lower sands by percolating through the higher beds it may be highly charged with calcium salts before reaching the bedrock formations containing bentonite or glauconite. The completeness of the exchange of calcium carbonate for sodium carbonate will, therefore, depend upon the length of time that the water is in contact with the softening reagent, and also upon the amount of this material present. The rate of movement of underground water will, consequently, be a factor in determining the extent of the reaction.

The amount of iron present in the water was not determined, owing to the possibilities of contamination from the iron casings in the wells. Iron is present in most waters, but the amount may be small. Upon exposure to air a red precipitate forms, the water becomes acid, and, hence, has a corrosive action. When iron is present in large amounts the water has an inky taste.

WATER ANALYSES IN RELATION TO GEOLOGY

Glacial Drift

The quality of the water from glacial drift depends largely on the nature of the deposit from which it comes and on the depth of the aquifer below the surface. Glacial deposits may be divided roughly into three types.

(1). Sand and gravel beds that form the surface deposit, such as outwash material and glacial lake sands.

(2). Buried outwash and interglacial deposits between two tills of boulder clay.

(3). Pockets or lenses of sand and gravel irregularly distributed through the till.

Water from surface sand deposits is normally low in dissolved salts, the total being generally less than 1,000 parts per million. Where large amounts of limestone occur in the glacial sand and gravel beds a characteristic constituent of the glacial water is calcium carbonate, the amount present varying from 300 to 700 parts per million.

Water from buried outwash deposits contains more dissolved salts than the surface sands, as the water in order to reach them has to percolate through overlying till. Rain water contains carbonic acid, which acts as a solvent and dissolves a great deal of calcium, magnesium, and sodium from the rock-forming minerals. Sulphate salts are commonly present, though their proportions vary greatly in the different waters. The shales that are incorporated in the drift are high in calcium sulphate, so that the amount of shale present will modify the quality of the water. The oxidized upper part of the drift contains less sulphate than the deeper, less oxidized boulder clay. The character of the water in the buried outwash deposits will, therefore, depend largely on the composition and amount of till that overlies it.

Water from irregularly distributed sand and gravel beds will vary in its content of dissolved salts depending upon the character of the material surrounding the reservoir beds. As the water in this type of deposit does not flow to any marked extent, it is apt to be more highly impregnated with soluble salts than where the underground movement is more rapid. Soft water in the drift is mostly confined to shallow wells in sands low in calcium carbonate. Waters from glacial lake clays are sometimes high in soluble salts. The sample from a well in glacial lake clay on N.W. $\frac{1}{4}$ sec. 27, tp. 42, rge. 17, has 11,040 parts per million of soluble salts, largely magnesium sulphate and sodium sulphate. The sample from SE. $\frac{1}{4}$ sec. 13, tp. 42, rge. 16, which is believed to come from glacial lake silts, has a very different composition. The total solids in it are only 440 parts per million, of which 250 are calcium carbonate. The great difference in these waters is due to the high soluble salt content that is associated with the lake clays but absent in the silts. Average drift water contains between 1,000 and 3,000 parts per million of dissolved mineral salts.

Bearpaw Formation

The Bearpaw formation consists of dark marine shales and beds of green sand. Water from these sands has a total solid count ranging from 300 to 1,600 parts per million and a hardness of more than 300 degrees. Calcium carbonate is very marked in all samples, due, perhaps, to the proximity of the water sands to the glacial drift. Sodium sulphate is the chief salt present, followed by calcium carbonate, magnesium sulphate, magnesium carbonate, and sodium chloride in decreasing amounts. These waters are distinguished from the overlying drift waters by being relatively low in total dissolved solids, and in containing no calcium sulphate and only moderate amounts of sodium sulphate, magnesium sulphate, and magnesium carbonate.

Pale Beds

Pale Beds underlie the Bearpaw formation. Total solids in waters from these beds vary from 700 to 1,300 parts per million. The water is, in most instances, soft, as it contains sodium carbonate in excess of calcium and magnesium carbonates, but when mixed with surface water high in calcium carbonate, it will become hard. The high concentration of sodium salts, especially sodium carbonate, in contrast with the calcium and magnesium salts distinguishes this water from that in Bearpaw sands. The Pale Beds include much bentonite, and it is this mineral that acts as a water softener within the formation. The following analyses are typical of waters from the Pale Beds:

Salts	SE. ¼ sec. 16, tp.38, rge. 21	NE. ¼ sec. 3, tp.39, rge. 25,	SW. ¼ sec. 7, tp.37, rge.24,	SE. ¼ sec. 21 tp. 38, rge.23
$CaCO_3$	73	18	53	35
$CaSO_4$	-	-	-	-
$MgCO_3$	52	14	45	38
$MgSO_4$	-	-	-	-
Na_2CO_3	297	679	464	562
Na_2SO_4	297	158	266	437

NaCl	31	45	46	130
Total solids	760	1,020	940	1,260
Hardness	100	20	30	75

Variegated Beds

In Senlac Rural Municipality, Saskatchewan, are a number of wells that have water very similar in character to that found in the Bearpaw formation. These wells tap an horizon that corresponds with the Variegated Beds in Alberta, although they have not been separated from the Pale Beds. They are less bentonitic than the Pale Beds and darker in colour. The water is hard and has a low dissolved solid content. The three analyses given below show a great deal of similarity and suggest a common horizon.

Salts	NW. sec. 21, tp.41, rge.26	NW. sec. 3, tp.41, rge.28	SE. sec. 28, tp.40, rge.28
$CaCO_3$	250	305	125
$CaSO_4$	-	-	-
$MgCO_3$	1109	80	155
$MgSO_4$	149	104	69
Na_2CO_3	-	-	-
Na_2SO_4	98	132	386
NaCl	12	12	18
Total solids	640	640	780
Hardness	600	600	500

Ribstone Creek Formation

Chemical analyses of water from the Ribstone Creek formation vary more than in the Pale Beds, the reason being that at several different horizons the sediments show considerable lateral variation. The formation includes both marine and non-marine beds, thin coal seams being present in the basal part of the formation around Paynton, whereas south of Lashburn, on Battle River, marine fossils were found in strata considered to be at approximately the same horizon. The water analyses show similarities within limited areas, but long distance correlations cannot be made safely except for the saline waters that occur in the flowing wells at Vera, Muddy Lake, and at the south end of Tramping Lake. Analyses of these waters are given in the following table:

Salts	SE.sec.25, tp.41, rge. 24	SE.sec.22, tp.41, rge. 24,	NE.sec.36, tp.41, rge. 24,	SW.sec.7 tp.41, rge 24,	SE.sec.30, tp.38, rge. 22,	SW.sec10, tp.35, rge.20,
$CaCO_3$	73	73	73	198	108	90
$CaSO_4$	-	-	-	-	-	-
$MgCO_3$	38	38	38	52	69	52
$MgSO_4$	-	-	-	-	-	-

Na_2CO_3	129	119	129	11	106	125
Na_2SO_4	55	55	61	61	49	43
NaCl	2,929	3,036	2,690	2,863	3,531	3,861
Total solids	3,840	3, 460	3,120	3,200	3,860	4,460
Hardness	135	90	110	100	130	130

The similarity in these anlayses suggests a common source bed. The distance between the Tramping Lake well and the Vera wells is about 40 miles. This water, which is thought to come from the basal sand of the Ribstone Creek formation, is not typical of water from the same stratigraphical horizon in the vicinity of Battle River, one reason being, possibly, that at Battle River the stream has cut through the Ribstone Creek formation exposing the sand members along its banks. This may cause a more rapid movement of the underground water in this area than farther south, and it is known that the rate of flow is a controlling factor that governs the change of calcium carbonate to sodium carbonate when the softening reagents of bentonite or glauconite are present in the sand.

Some of the soft waters from the Ribstone Creek formation cannot be distinguished from those of the Pale Beds, whereas others are quite different. The following analyses illustratetsome of the different types of water from this formation:

Salts	Se.sec. 11, tp. 46, rge. 28	Ind.Agent Little Pine I.R.	SW.sec. 24, tp. 46, rge. 21	NE.sec. 36, tp. 43, rge. 18	Se.sec. 26. tp. 43, rge. 18	NE.sec. 36. tp. 41, rge. 24	NW.sec. 22. tp. 42. rge. 23
$CaCO_3$	90	90	410	73	35	73	125
$CaSO_4$	-	-	-	-	-	-	-
$MgCO_3$	97	59	168	38	31	38	97
$MgSO_4$	-	-	64	-	-	-	-
Na_2CO_3	217	392	-	283	592	129	196
Na_2SO_4	1,644	777	2,518	225	522	61	1,541
NaCl	249	63	76	12	83	2,690	71
Total solids	2,220	1,340	3,000	620	1,280	3,120	1,900
Hardness	280	160	750	110	35	110	600

The above chemical analyses show such a wide range in the dissolved salts present in the different waters in the Ribstone Creek formation that they cannot be used for correlation purposes over a large area.

Conclusions

(1) In most instances water from glacial drift is quite different from water from bedrock.

(2) Some of the bedrock horizons carry waters that show definite chemical characteristics.

(3) Most waters from glacial till carry total solids amounting to between 1,000 and 3,000 parts per million.

(4) Bedrock waters are commonly low in dissolved salts. Exceptions to this are to be found in water from the Ribstone Creek formation.

(5) Water from the Bearpaw formation is hard. An average of ten wells gave a total solid content of 1,100 parts per million.

(6) Water from the Variegated Beds resembles that from the Bearpaw formation.

(7) Waters from the Pale Beds is mostly soft. An average of ten wells gave a total solid of 1,000 parts per million.

(8) All soft waters contain sodium carbonate (Na_2CO_3), which is present in water from the Pale Beds and Ribstone Creek formations but absent from the Bearpaw formation and Variegated Beds.

RURAL MUNICIPALITY OF NORTH STAR, NO. 531, SASKATCHEWAN

Physical Features

The north-south drainage pattern is an outstanding topographical feature of this municipality. Englishman River on the east and Monnery River on the west are the largest of these streams. Between them are several smaller valleys in the northern part of the municipality. Small streams meander through these deeply eroded valleys, which were formed and cut to their present level by water from the melting continental ice-sheet. The large quantities of water that flowed southerly across the area modified the topography from that of a comparatively flat plain sloping gently to the south into one with deep valleys and numerous small gullies. Most of the lakes in the area are small and are of glacial origin.

Geology

So far as can be determined Lea Park shales underlie the surface deposits, although there are no exposures of the strata in the municipality. Several outcrops occur along Glenbogie Creek in sec. 32, tp. 52, rge. 24, at an elevation of 1,830 feet. The surface rises to the north, and a large part of the municipality has an elevation greater than 2,100 feet. This may be due, in part, to an increased thickness of drift in that direction, but it is also possible that higher beds stratigraphically may be present on the higher land, though the only supporting evidence is that of small fragments of sandstone, resembling that from the Ribstone Creek formation, along the banks of Monnery River. As no outcrops were found it appears that the river channel has not cut through the glacial material into bedrock, and that sandstone fragments may have been distributed by glacial agencies. On the assumption that the channel of Monnery River has not cut into bedrock, the thickness of the drift must be greater than 150 feet.

Water Supply

The surface deposit of glacial material is important because it contains the aquifers that supply the municipality with water. It varies considerably in composition as it was partly reworked by streams from the retreating continental glacier. These streams and flood waters left deposits of sand and gravel, many of which were subsequently covered with boulder till. The glacial streams that eroded the present drainage channels left large deposits of sand on the lower land in tp. 53, rge. 24, from which water is easily obtained. The drift is believed to increase in thickness northward, but its content of sand and gravel may decrease in the same direction, as the drift has not been subjected to the same degree of sorting there as farther south.

As it is improbable that bedrock sand underlies the drift, the possibilities of obtaining water below the surface deposits are not good.

Township 53, Range 22. Englishman River Valley shows a marked change in character in section 14 of this township. To the south the valley is broad and has the appearance of an old channel, whereas to the north the river is entrenched in a narrower, deeper valley, eroded into the glacial drift, which forms a thick surface deposit. On the high land adjoining the valley wells have been dug to depths of more than 100 feet without penetrating the drift. The lowest aquifer, at an elevation of 1,893 feet, is glacial gravel. It is located, however, in a valley that may be of pre-glacial age, and thus the bedrock may be much higher to the west. The large ridge that parallels the river to the west is composed almost entirely of boulder clay with scattered pockets and lenses of sand and gravel. Most of the aquifers penetrated by wells on this ridge have elevations ranging between 2,025 and 2,005 feet and may derive their water from several sands. On NW. section 16 a well bored to a depth of 106 feet yields a good supply of water in gravel at an elevation of 1,931 feet, much lower than at any other well in the immediate vicinity. Even if this gravel deposit is only a local pocket it at least indicates that similar deposits may be encountered elsewhere in the lower part of the drift. Along Englishman River several large sand and gravel deposits yield a good supply of water at comparatively shallow depths. The elevations of these aquifers range from 1,917 feet on section 10 to 1,985 feet on section 26. On the higher land east of Englishman River conditions are believed to be similar to those west of the river.

Township 53, Range 23. The surface deposits of this township have been greatly modified by streams from the retreating ice-mass that at one time covered the region. These waters eroded the boulder till from the higher land and deposited sand and gravel on the lower plains. The course now occupied by Glenbogie Creek was the main channel for a large stream that left a large sand and gravel deposit along its course. These beds of sorted material form the surface deposit of most of the western part of the township. A similar drainage channel, which carried a large amount of water from the north into Englishman River, trends almost north and south on the east side of the township. Between these two drainage channels boulder till forms a ridge of high land.

No outcrops of the underlying bedrock are exposed in the township but from regional information it is reasonable to expect that the Lea Park shale underlies the drift. This is important, as, if true, the water supply is probably confined to the glacial material that overlies the shale. Specific information regarding the drilled wells at Paradise Hill and Bolney is lacking, so that no definite information on the character of the Lea Park formation is available although it is thought to be composed entirely of shale.

The water supply is on the whole adequate, and is obtained from wells ranging in depth from 12 to 42 feet. Several springs occur along the stream channels at different elevations. On sections 19 and 30 the elevations of the springs are 1,870 and 1,890 feet respectively, whereas on section 24 the level of a large spring is 2,020 feet above sea-level. Most of the wells on the sandy plain have aquifers whose levels approximate those of the springs on sections 19 and 30. These surface deposits have a high porosity and thus make excellent aquifers at shallow depths. They are, however, irregularly distributed through the drift and can only be located by test drilling. In the higher land to the east the water horizons have a wide range of elevations in the boulder till, and several aquifers are present. Those in the upper part of the drift are adequate for present requirements. Others no doubt occur at greater depths but their maximum vertical range is unknown as the thickness of the drift has not been determined.

Township 53, Range 24. Monnery River, with its many small tributaries, is the chief topographic feature in this township. It is evident from the size of the main valley that great quantities of water flowed through this channel shortly after the continental ice-sheet had retreated to the north and water from the melting ice found its way into the Saskatchewan through Monnery River Valley. The large sand deposits around Perch Lake suggest that much of this water entered Monnery River from the northeast in sections 8 and 17. These waters left huge deposits of sand that were subsequently eroded by Monnery River, resulting in rolling sand hills in the vicinity of Birch Lake.

Exposures of Lea Park shale are found on Glenbogie Creek and in the railroad cuts on section 32 in the township to the south. This shale is, therefore, believed to underlie the surface deposits of sand and boulder till. The depth to the shale naturally varies with the surface elevations, but as no wells have penetrated the surface deposits only an estimate of its possible thickness can be made. In the sandy area and low land along Monnery River the depth to the shale is probably less than 50 feet, but on the higher land to the north it increases to more than 100 feet. The deepest well in the township was bored on NE. section 26 to a depth of 85 feet, where, so far as can be determined, it was in glacial material. No exposures of the bedrock strata were discovered along the river banks, but small fragments of sandstone resembling material from the Ribstone Creek formation, which overlies the Lea Park shale, were found on the surface. Because of a rumour that coal had been found along this river in the early days a thorough search was made for evidence of this. The Ribstone Creek formation is known to carry thin coal seams near its base, and for this reason the discovery of coal fragments along the river valley would indicate that this formation is present on the higher land to the north. Further, the sand members of the Ribstone Creek associated with the coal are generally good aquifers. However, no definite proof was found to support the suoposition that coal is present.

Most of the water obtained in the sandy area is found at shallow depths during periods of normal rainfall, but a continuous drought affects the supply by lowering the water-table. This necessitates deepening the wells to the impervious layers of shale that underlie the sand and boulder till.

On the higher land to the north water is not as readily obtained in the surface deposit of boulder till. The wells there have a greater depth range, and there does not appear to be any marked uniformity in the levels of the water horizons.

Township 54, Range 22. The boulder till that forms the surface deposit in this township is fairly well drained by several streams flowing to the south in rather deep broad valleys. These stream channels were eroded by the waters from the retreating continental ice-mass. The surface is somewhat rolling, and characteristic morainal hills occur in sections 5, 6, 7, and 8 as well as elsewhere in the township.

The thickness of the surface deposit of glacial drift is not definitely known as no wells have reached the underlying bedrock. The nearest exposure of bedrock is found on Glenbogie Creek to the southwest, and is an impervious shale of the Lea Park formation. The elevation of the top of this shale is 1,830 feet. It is possible that higher beds stratigraphically may be present in this township as the land surface lies 200 to 300 feet above the outcrop, but otherwise the deposit of glacial material may be the only source of potable water in this area. A knowledge of the nature of this deposit is, therefore, essential in understanding the occurrence of ground-water supplies.

Extensive sand and gravel deposits are not common in this district. Such deposits when buried between two tills of boulder clay indicate a minor retreat of the ice followed by a subsequent advance. Small, local retardations, on the other hand, are common and are represented by many sand and gravel deposits of limited size.

In this township the surface deposit is a boulder till containing buried sand and gravel beds, lenses, and pockets. The water supply is obtained from these deposits, which are reached at various depths ranging between 10 to 72 feet, with most of them less than 30 feet below the surface. The fact that all of the deeper wells obtain a good supply of water is proof of the large, aggregate quantity of sand and gravel distributed through the boulder till. The upper 30 feet contains much sorted material, especially sand, but it cannot always be relied upon to yield the required amount of water, and deeper digging, therefore, becomes necessary. It is doubtful if extensive buried sand and gravel deposits are present, but numerous small deposits and pockets can be grouped together in definite horizons.

The upper horizon yields a good supply of water in sections 7, 8, and 17, at elevations between 2,112 and 2,130 feet. All of the wells in these sections are less than 30 feet deep. The lowest horizon reached is on section 10 at a depth of 72 feet, or an elevation of 2,029 feet, and other aquifers occur at levels intermediate between these two horizons throughout the township. Still lower horizons are undoubtedly present, but as the thickness of the drift is not known it can only be stated in a general way that water possibilities should be equally good to the base of the drift.

Township 54, Range 23. In this township the surface deposit of boulder till is fairly well drained by several small parallel drainage channels that carry the run-off waters to the south and finally into Saskatchewan River. These deep ravines were formed in earlier time by large quantities of water from the melting of the continental glacier on its retreat to the north. The topography is slightly rolling, with a few small moraines at various places.

Bedrock strata are everywhere covered by drift whose thickness is unknown because no wells have been dug through it. On Glenbogie Creek, in sec. 32, tp. 52, rge. 24, the elevation of the shale surface is 1,830 feet. It is probable that this surface rises with the surface topography to the north and that higher beds stratigraphically may be present there. The glacial drift is, however, believed to thicken towards the north, and, therefore, accounts for part of the difference in surface elevation in that direction.

The ground-water supply is obtained wholly from the glacial drift. The water-bearing sand and gravel deposits encountered in most of the wells lie at a depth of less than 20 feet, so that the upper part of the drift can be considered to be very porous. At several places water in sufficient quantities has not been obtained in the upper 20 feet but from depths of less than 45 feet. As there are no dry holes, it is evident that sand and gravel bodies are very generally distributed to at least this depth and may be expected to yield a good supply of water.

Lower aquifers will undoubtedly be encountered at greater depths within the glacial deposit. The total thickness of the drift is not known, but is estimated to be more than 100 feet. If shale occurs below the drift, water possibilities in it are poor, but if higher beds, represented by a sandstone, should be present the chances of encountering an extensive aquifer are good.

Township 54, Range 24. The surface deposit of boulder clay left by the continental ice-sheet in this township was reworked to some extent by the large quantities of water from the melting of the retreating continental glacier. Monnery River Valley is believed to have been eroded at that time, and carried a large volume of water into the Saskatchewan. The land adjoining this drainage channel is a relatively flat ground-moraine deposit. The river has entrenched itself to depths of between 150 and 200 feet, but no evidence of the bedrock formation underlying the drift was found along the stream or along the banks.

Several large springs issue from a glacial sand on the east bank of Monnery River at what appears to be about the same elevation, at 1,973 feet. It is possible that the springs indicate the top of an impervious bedrock stratum of shale, but no evidence is available to support this possibility. Large blocks of calcareous tufa were found along the bank, showing that the spring waters are high in lime.

The wells vary greatly in depth and in the amount of water yielded, suggesting that the sand and gravel aquifers in the drift are irregular in size and distribution. Their depths range from 12 to 70 feet, and the deeper wells are reported to yield less than those nearer the surface, indicating that the upper 40 feet of drift contains more sand and gravel than the deeper parts. Judging from the large number of wells that have aquifers with elevations between 2,030 and 2,060 feet, it seems very reasonable to assume a nearly continuous water-bearing horizon across the central part of the township on both sides of the river. Lower aquifers can be expected in the drift, but so far have proved less productive than those at shallower depths. The total thickness has been estimated to be more than 150 feet, as no outcrops were found along Monnery River. Prospects of water in the strata below the surface till are not considered good, no evidence having been obtained to indicate the presence of a sand member in the formation.

Township 55, Range 22. The ground-water conditions in the southern part of this township are very similar to those of the township to the south. Water is obtained in the upper part of the drift at somewhat higher elevations, the rise in the water-table to the north being due chiefly to a rise in the land surface in that direction. The thickness of the drift is believed to increase towards the north as the surface becomes more broken and morainal in character.

Township 55, Range 23. Almost all of this township lies within the boundaries of the forest reserve where a study of the water resources has not been made. It is probable, however, that conditions are similar to those in the adjoining townships to the south.

Township 55, Range 24. The surface deposit of glacial drift in this township has characteristics of both ground moraine and recessional moraines. The latter are small, and extend along the east and west sides of the township with fairly flat areas between them. No bedrock outcrops are exposed in this township or in the immediate vicinity, and for this reason it is difficult to determine either the thickness of the surface deposit or the character of the underlying bedrock. Lea Park shale outcrops on Pipestone Creek to the southwest and on Glenbogie Creek to the south, but too far distant to make further interpretations possible. From the nature of the surface deposit it would appear that the drift is more than 100 feet thick.

Water is obtained from wells in the upper part of the till. These wells range in depth from 10 to 35 feet and a fair supply of water is obtained from sand and gravel bodies and lenses that are irregularly distributed throughout the upper part of the deposit. Deeper digging will without doubt reveal further such bodies that will yield a fair amount of water. These aquifers are of local extent, and it is, therefore, difficult to predict the depth at which they will be found.

ANALYSES OF WATER SAMPLES FROM RURAL MUNICIPALITY OF NORTH STAR, No.531, SASKATCHEWAN.

						CONSTITUENTS AS ANALYSED							CONSTITUENTS AS CALCULATED IN ASSUMED COMBINATIONS							
No.	Sect.	Tp.	R.	Depth of well in ft.	Total diss'd solids	Ca	Mg	Na	SO_4	Cl	Alkalinity	Total hardness	$CaCO_3$	$CaSO_4$	$MgCO_3$	$MgSO_4$	Na_2CO_3	Na_2SO_4	NaCl	Remarks
1	NW 5	54	22	32	14,010	1673	578	849	168	5480	515	3000	515	239	($CaCl_2$ 3880)		($MgCl_2$ 2265)		2160	Glacial

WELL RECORDS—Rural Municipality of NORTH STAR, No. 531, SASKATCHEWAN.

WELL No.	LOCATION ¼	Sec.	Tp.	Rge.	Mer.	TYPE OF WELL	DEPTH OF WELL	ALTITUDE WELL (above sea level)	HEIGHT TO WHICH WATER WILL RISE Above (+) Below (−) Surface	Elev.	PRINCIPAL WATER-BEARING BED Depth	Elev.	Geological Horizon	CHARACTER OF WATER	TEMP. OF WATER (in °F.)	USE TO WHICH WATER IS PUT	YIELD AND REMARKS
	SW	1	53	22	3	dug	35	2055	- 33	2022	35	2020	Glacial	hard		D.S.	Good supply in gravel
	NW	5				"	52	1959	- 26	1933	52	1907	"	"		D.S.	Good supply in sand
	SE	5				bored	35	1936	- 15	1921	35	1901	"	"		D.S.	Good supply in sand
	SE	7				dug	75	2000					"			D.S.	Dry hole. Well beside lake 9' deep elevation 1913.
	NW	8				dug	32	2075	- 28	2047	32	2043	"	hard		D.S.	Limited supply in sand
	NW	10				"	10	1927			10	1917	"	"		D.S.	Good supply in gravel
	SE	10				"	44	1993	- 42	1951	44	1949	"	"		D.S.	Good supply in gravel
	NE	10				"	56	1998			56	1942	"	"		D.S.	Good supply in sand and gravel
	SE	15				"	20	1958			20	1938	"	"		D.S.	Limited supply
	NW	16				bored	106	2037	100	1937	106	1931	"	"		D.S.	Good supply in gravel
	SE	16				"	54	1947			54	1893	"	"		D.S.	Seepage supply in blue clay
	SW	17				"	65	2088			55	2033	"	"		D.S.	Good supply in sand
	NW	18				dug	35	2120	- 30	2090	35	2085	"	"		D.S.	Good supply in gravel and sand
	NW	20				"	30	2095	- 22	2073	30	2065	"	"		D.S.	Good supply in gravel
	NE	20				bored	66	2081	- 56	2025	66	2015	"	"		D.S.	Good supply in sand. Dryhole 97 feet
	NE	21				"	50	2058	- 25	2033	50	2008	"	"		D.S.	Good supply in fine sand
	SE	22				"	60	2031			60	1971	"	"		D.S.	Limited supply
	NE	23				"	9	1986			9	1977	"	"		D.S.	Good supply in gravel
	NW	24				"	22	2006	- 16	1990	22	1984	"	"		D.S.	Good supply in sand
	SE	26				"	30	1997	- 16	1981	30	1967	"	"		D.S.	Good supply.
	SW	26				"	64	2049	- 30	2019	64	1985	"	"		D.S.	Good supply
	SE	27				dug	60	2062	- 25	2037	60	2002	"	"		D.S.	Good supply in sand
	NW	27				bored	64	2081	- 44	2037	64	2017	"	"		D.S.	Good supply
	NE	30				dug	40	2118	- 30	1988	40	2078	"	"		D.S.	Limited supply in sand
	SE	31				"	28	2121	- 20	2101	28	2093	"	"		D.S.	Good supply
	NW	31				"	18	2069	- 16	2053	18	2051	"	"		D.S.	Limited supply
	NE	32				"	45	2122	- 41	2081	45	2077	"	"		D.S.	Limited supply in sand
	NE	36				"	30	2092			30	2062	"	"		D.S.	Limited supply in sand
	SE	1	53	23	3	dug	18	1916	- 16	1900	18	1898	Glacial	hard		D.S.	Good supply in sand
	SW	2				"	12	1920	- 10	1910	12	1908	"	soft		D.S.	Good supply in gravel
	SE	4				"	12	1920	- 10	1910	12	1908	"	hard		D.S.	Limited supply
	SW	4				"	22	1915	- 10	1905	22	1893	"	"		D.S.	Good supply in silt
	SE	6				"	14	1895	- 12	1883	14	1881	"	"		D.S.	Good supply in gravel
	SW	8				"	16	1885	- 14	1871	16	1869	"	"		D.S.	Good supply in fine sand
	SE	8				"	42	1920	- 35	1885	42	1878	"	"		D.S.	Good supply in sand
	SE	13				"	27	2020	- 24	1996	27	1993	"	"		D.S.	Limited supply
	SE	14				"	40	1960	- 20	1940	40	1920	"	"		D.S.	Good supply in sand
	NW	16				"	23	1925	- 18	1907	23	1903	"	"		D.S.	Continuous flow
	NE	19				Spring		1870				1870	"	"		D.S.	Good supply in fine sand
	SE	20				dug	29	1911	- 25	1886	29	1882	"	"		D.S.	Good supply in fine sand
	SW	21				"	17	1906	- 12	1894	17	1889	"	"		D.S.	Good supply in fine sand
	SW	24				Spring		2020					"	"		D.S.	Good supply
	NW	24				dug	30	2020	- 25	1995	30	1990	"	"		D.	Limited supply in sand
	SW	26				"	18	2060	- 15	2045	18	2042	"	"		D.S.	Good supply in sand
	SE	27				bored	42	1956	- 34	1922	42	1914	"	"		D.S.	Limited supply in sand
	SW	28				dug	30	1950	- 24	1926	30	1920	"	"		D.S.	Good supply in sand
	SW	30				Spring		1890				1890					Continuous flow
	SE	32				Spring	35	1956			35	1921	"	"		D.S.	Good supply in sand
	NE	33				"	20	1966	- 18	1948	20	1946	"	"		D.S.	Good supply in sand and gravel
	NE	36				"	25	2051	- 20	2031	25	2026	"	"		D.S.	Limited supply in sand
	NW	22				bored	30	1940	- 28	1912	30	1910	"	"		D.S.	Good supply in fine sand

NOTE—All depths, altitudes, heights and elevations given above are in feet.

(D) Domestic; (S) Stock; (I) Irrigation; (M) Municipality; (N) Not used.
(#) Sample taken for analysis.

WELL No.	LOCATION ¼	Sec.	Tp.	Rge.	Mer.	TYPE OF WELL	DEPTH OF WELL	ALTITUDE WELL (above sea level)	HEIGHT TO WHICH WATER WILL RISE Above (+) Below (−) Surface	Elev.	PRINCIPAL WATER-BEARING BED Depth	Elev.	Geological Horizon	CHARACTER OF WATER	TEMP. OF WATER (in °F.)	USE TO WHICH WATER IS PUT	YIELD AND REMARKS
1	NW	2	53	24	3	dug	4	1847			4	1843	Glacial	hard		D.S.	Good supply in gravel
2	SW	3				"	8	1816			8	1808	"	"		D.S.	Good supply
3	SE	4				"	30	1835			30	1805	"	"		D.S.	Limited supply in sand
4	SW	5				"	20	1800	- 18	1782	20	1780	"	"		D.S.	Good supply in sand
5	SW	12				"	14	1839	- 10	1829	14	1825	"	"		D.S.	Good supply in sand
6	SE	14				"	24	1865			24	1841	"	"		D.S.	Limited supply in sand
7	SW	15				"	10	1810			10	1800	"	"		D.S.	Good supply in gravel
8	SW	19				"	14	2040	- 12	2028	14	2026	"	soft		D.S.	Good supply
9	NW	20				Spring		1835					"	hard		D.S.	Good supply
10	NW	21				"		1830					"	soft		D.S.	Good supply
11	SE	24				"		1859					"	"		D.S.	Good supply
12	NE	25				dug	20	1932	- 19	1913	20	1912	"	hard		D.S.	Limited supply. Spring at 1862 feet
13	NE	26				bored	85	2033	- 82	1951	85	1948	"	"		D.S.	Limited supply
14	SE	28				dug	20	1808	- 17	1791	20	1788	"	"		D.S.	Good supply in fine sand
15	SW	30				"	20	2050	- 15	2035	20	2030	"	"		D.S.	Good supply
16	NW	30				"	8	2012			8	2004	"	"		D.S.	Good supply in sand
	NE	31				"	70	2068	- 67	2001	70	1998	"	"		D.S.	Sufficient supply
17	SW	32				"	46	1990	-44	1946	46	1944	"	"		D.S.	Limited supply in sand
18	SE	32				"	14	1920			14	1906	"	"		D.S.	Good supply in sand
19	SW	34				Spring		1913					"	"		D.S.	Good supply
20	NE	35				dug	50	1997			50	1947	"	"		D.S.	Limited supply in sand
21	NE	36				"	35	2017	- 25	1992	35	1982	"	"		D.S.	Good supply in sand

WELL No.	LOCATION ¼	Sec.	Tp.	Rge.	Mer.	TYPE OF WELL	DEPTH OF WELL	ALTITUDE WELL (above sea level)	HEIGHT TO WHICH WATER WILL RISE Above (+) Below (−) Surface	Elev.	PRINCIPAL WATER-BEARING BED Depth	Elev.	Geological Horizon	CHARACTER OF WATER	TEMP. OF WATER (in °F.)	USE TO WHICH WATER IS PUT	YIELD AND REMARKS
1	NE	2	54	22	3	dug	65	2110			65	2045	Glacial	soft		D.S.	Good supply in sand
2	SE	3				"	27	2067	- 21	2046	27	2040	"	hard		D.S.	Good supply in clay
3	SW	4				"	30	2081	- 25	2056	30	2051	"	"		D.S.	Good supply in sand
4	NE	4				"	14	2049			14	2035	"	"		D.S.	Good supply in sand
5	NE	5				"	61	2121	- 31	2090	61	2060	"	"		D.S.	Good supply in sand and gravel
6	NE	5				"	13	2072			13	2059	"	"		D.S.	Good supply in sand
7	NW	6				"	20	2067	- 15	2052	20	2047	"	"		D.	Sufficient. Similar well for stock
8	SE	7				"	26	2138	- 25	2113	26	2112	"	"		D.	Limited supply in clay
9	SW	8				"	15	2139	- 12	2127	15	2124	"	"		D.S.	Good supply in sand
10	SW	9				"	38	2136			38	2098	"	"		D.S.	Good supply in clay
11	NE	10				"	72	2101	- 69	2032	72	2029	"	"		D.S.	Good supply in sand
12	NE	13				"	22	2083			22	2061	"	soft		D.S.	Good supply in sand
13	SW	17				"	27	2142			27	2115	"	hard		D.S.	Limited supply in sand
14	NW	17				"	24	2153	- 21	2132	24	2129	"	"		D.S.	Good supply in sand
15	SE	17				"	30	2142	- 24	2118	30	2112	"	"		D.S.	Good supply in sand
16	SW	19				"	15	2088			15	2073	"	"		D.S.	Good supply in sand
17	SW	20				"	47	2134	- 45	2089	47	2087	"	"		D.S.	Good supply in sand
18	SW	21				"	35	2154			35	2119	"	soft		D.S.	Good supply in sand
19	NW	25				"	16	2066			16	2050	"	hard		D.S.	Good supply in fine sand
20	SW	25				"	33	2085			33	2052	"	"		D.S.	Good supply in sand
21	SW	27				"	63	2128			63	2065	"	"		D.S.	Good supply in sand
22	NE	28				"	15	2143			15	2128	"	"		D.S.	Good supply in sand
23	SE	30				"	12	2148	- 9	2139	12	2136	"	"		D.S.	Good supply in sand
24	NW	31				"	10	2106	- 4	2102	10	2096	"	soft		D.S.	Good supply in gravel
25	SW	32				"	27	2149			27	2122	"	hard		D.S.	Limited supply
26	NE	33				"	12	2170			12	2158	"	soft		D.S.	Good supply in sand
27	NW	34				"	32	2153			32	2121	"	"		D.S.	Good supply in clay

NOTE—All depths, altitudes, heights and elevations given above are in feet.

(D) Domestic; (S) Stock; (I) Irrigation; (M) Municipality; (N) Not used.
(#) Sample taken for analysis.

WELL RECORDS—Rural Municipality of NORTH STAR No. 531

WELL No.	LOCATION ¼	Sec.	Tp.	Rge.	Mer.	TYPE OF WELL	DEPTH OF WELL	ALTITUDE WELL (above sea level)	HEIGHT TO WHICH WATER WILL RISE Above (+) Below (−) Surface	Elev.	PRINCIPAL WATER-BEARING BED Depth	Elev.	Geological Horizon	CHARACTER OF WATER	TEMP. OF WATER (in °F.)	USE TO WHICH WATER IS PUT	YIELD AND REMARKS
1	SE	1	54	23	3	dug	16	2033	- 12	2021	16	2017	Glacial	hard		D.S.	Good supply in sand
2	SW	1				"	10	2044	- 7	2037	10	2034	"	"		D.S.	Good supply in sand and gravel
3	NE	1				"	25	2075	- 23	2052	25	2050	"	"		D.S.	Limited supply in gravel
4	SW	2				"	18	1942			18	1924	"	"		D.	Limited supply in blue clay
5	SE	4				"	9	1977	- 5	1972	9	1968	"	"		D.S.	Good supply in gravel
6	SW	5				"	20	1974	- 16	1958	20	1954	"	"		D.S.	
7	SE	5				"	17	1978	- 15	1963	17	1961	"	"		D.S.	Good supply in sand
8	NW	6				"	35	2069	- 32	2037	35	2034	"	"		D.S.	Good supply in sand
9	NE	9				"	18	2020	- 16	2004	18	2002	"	"		D.S.	Limited supply in sand
10	SE	10				"	18	2031	- 11	2020	18	2013	"	"		D.S.	Good supply in gravel
11	NW	10				"	7	1993			7	1986	"	"		D.S.	Good supply in blue sand
12	SE	12				"	12	2068	- 8	2060	12	2056	"	"		D.S.	Good supply in sand
13	SW	13				"	12	2088	- 9	2079	12	2076	"	"		D.S.	Good supply in gravel
14	NW	14				"	14	2107	- 11	2096	14	2093	"	"		D.S.	Good supply in clay
15	SW	15				"	12	2045			12	2033	"	"		D.S.	Limited supply in blue clay
16	NE	15				"	27	2099	- 21	2078	27	2072	"	"		D.S.	Limited supply
17	NW	16				"	12	2076	- 9	2067	12	2064	"	"		D.S.	Good supply in sand
18	NE	17				"	20	2072	- 16	2056	20	2052	"	"		D.S.	Good supply in sand
19	SE	18				"	16	2066	- 8	2058	16	2050	"	"		D.S.	Good supply in gravel
20	NE	20				"	44	2145	- 40	2105	44	2101	"	"		D.S.	Good supply in fine sand
21	SW	21				"	10	2083	- 6	2077	10	2073	"	"		D.S.	Good supply in fine sand
22	NW	22				bored	40	2132	- 37	2095	40	2092	"	"		D.	Good supply in sand
23	SW	23				dug	7	2115			7	2108	"	"		D.S.	Good supply in sand
24	SW	24				"	30	2088			30	2058	"	"		D.S.	Limited supply in clay
25	SE	25				"	35	2141	- 32	2109	35	2106	"	"		D.S.	Good supply in gravel
26	NE	26				"	12	2125			12	2113	"	"		D.S.	Limited supply in clay
27	NW	27				"	20	2141			20	2121	"	"		D.S.	Limited supply in sand
28	SE	28				"	10	2070	- 7	2063	10	2060	"	"		D.S.	Good supply in fine sand
29	SW	34				"	16	2150	- 12	2138	16	2134	"	"		D.S.	Good supply in sand
30	SW	36				"	6	2128			6	2122	"	"		D.S.	Good supply in gravel
1	NW	2	54	24	3	dug	55	2041			55	1986	Glacial	soft		D.	Poor supply in sand
2	SE	3				Spring		1967				1967	"	hard		D.S.	Continuous flow
3	SW	4				dug	12	2018	- 10	2008	12	2006	"	"		D.S.	Limited supply in sand and gravel
4	NW	4				"	14	2092			14	2078	"	"		D.S.	Good supply in sand and gravel
5	SW	5				"	13	2068			13	2055	"	soft		D.S.	Limited supply in gravel
6	SE	6				"	30	2060	- 26	2034	30	2030	"	hard		D.S.	Good supply in gravel
7	SE	7				"	16	2060			16	2044	"			D.S.	Limited supply in gravel
8	NE	8				"	70	2110			70	2040	"	"		D.S.	Limited supply in sand
9	SE	12				"	40	2059	- 35	2024	40	2019	"	"		D.S.	Good supply in sand and gravel
10	NE	13				"	32	2127	- 28	2099	32	2095	"	"		D.S.	Good supply in sand
11	NE	15				"	24	2074			24	2050	"	"		D.S.	Good supply in sand
12	NW	16				"	30	2148			30	2118	"	"		D.S.	Limited supply in clay
13	SE	18				"	50	2092			50	2042	"	"		D.S.	Good supply in gravel
14	NW	19				"	36	2148			36	2112	"	"		D.S.	Good supply in clay
15	SW	21				"	13	2072	- 10	2062	13	2059	"	"		D.S.	Good supply in gravel
16	NW	23				"	19	2059	- 17	2042	19	2040	"	"		D.S.	Good supply in fine sand
17	NE	24				"	7	2138			7	2131	"	"		D.S.	Limited supply
18	SE	25				"	60	2161			60	2101	"	"		D.S.	Limited supply in sand
19	NE	26				"	12	2118			12	2106	"	soft		D.S.	Good supply in gravel
20	SE	26				"	12	2108	- 10	2098	12	2096	"	"		D.S.	Limited seepage supply
21	SW	28				"	20	2065			20	2045	"	hard		D.S.	Limited supply in clay

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(#) Sample taken for analysis.

WELL RECORDS—Rural Municipality of NORTH STAR No. 531

WELL No.	LOCATION ¼	Sec.	Tp.	Rge.	Mer.	TYPE OF WELL	DEPTH OF WELL	ALTITUDE WELL (above sea level)	HEIGHT TO WHICH WATER WILL RISE: Above (+) Below (−) Surface	HEIGHT TO WHICH WATER WILL RISE: Elev.	PRINCIPAL WATER-BEARING BED: Depth	PRINCIPAL WATER-BEARING BED: Elev.	PRINCIPAL WATER-BEARING BED: Geological Horizon	CHARACTER OF WATER	TEMP. OF WATER (in °F.)	USE TO WHICH WATER IS PUT	YIELD AND REMARKS
22	SE	30	54	24	3	dug	38	2133			38	2095	Glacial	hard		D.S.	Good supply in clay
23	NW	32				"	16	2090	- 14	2076	16	2074	"	soft		D.S.	Good supply in sand
24	SW	34				"	18	2068			18	2050	"	hard		D.S.	Good supply in fine sand
25	NE	34				"	40	2047			40	2007	"	soft		D.S.	Limited supply in sand
1	SE	1	55	22	3	dug	36	2110			36	2074	Glacial	hard		D.S.	Good supply in gravel
2	SE	3				"	10	2198			10	2188	"	"		D.S.	Good supply in sand
3	SE	6				"	38	2146	- 35	2111	38	2108	"	"		D.S.	Good supply in sand
4	NE	12				"	15	2188			15	2173	"	"		D.	Limited supply in clay
1	SW	6	55	23	3	dug	20	2127			20	2107	Glacial	hard		D.	Limited supply in gravel
2	SW	18				"	8	2113	- 6	2107	8	2105	"	"		D.S.	Good supply in clay
1	NE	1	55	24	3	dug	26	2125	- 25	2100	26	2099	Glacial	hard		D.	Limited supply
2	NE	2				"	25	2063	- 23	2040	25	2038	"	"		D.S.	Good supply in fine sand
3	SE	3				"	18	2108			18	2090	"	"		D.S.	Good supply in fine sand
4	SE	5				"	18	2073			18	2055	"	soft		D.S.	Just enough in sand
5	SE	6				"	24	2122	- 19	2103	24	2098	"	hard		D.S.	Good supply in sand
6	NE	10					12	2074	- 9	2065	12	2062	"	soft		D.	Limited supply in gravel
7	SE	12				"	12	2094	- 11	2083	12	2082	"	hard		D.S.	Sufficient supply in gravel
8	NW	18				"	10	2048	- 9	2039	10	2038	"	"		D.	Insufficient in sand
9	NW	21					35	2097	- 32	2065	35	2062	"	"		D.	Insufficient in clay
10	SW	26				"	22	2123	- 21	2102	22	2101	"	"		D.S.	Insufficient in clay
11	SE	28				"	27	2104			27	2077	"	"		D.S.	Good supply in clay

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(#) Sample taken for analysis.